

SPECTROPHOTOMETRIC COMPARISON OF MARTIAN CONTINENTS
WITH RED-COLORED TERRESTRIAL CAPROCK

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Relative spectral curves of the integral Martian radiation in the visual region are plotted, using the published data. The same curves are drawn for the brightness of continents in the center of the disk of the planet, taking into account the optical effect of Martian atmosphere. The curves are compared with the curves of spectral reflectance of red-colored terrestrial rocks. The latter are determined with the SF-2M spectrophotometer. Satisfactory coincidence of these curves may be considered as confirmation of the hypothesis according to which the specific color of the Martian surface is attributed to the presence of a limonite dust.

Author

The optical properties of the Martian surface and of the earth's mantle have previously been compared mainly on the basis of the data of colorimetry or of photometry in broad spectrum regions, cut out by optical filters. These investigations, and specifically the studies by V.V. Sharonov (Bibl.1 - 3), showed that various types of natural depositions, strongly colored by limonite, reasonably resemble Martian continents with respect to the luminosity r and to the yellow color index D . For example, $r = 0.18$ and $D = 1.01$ have been obtained for iron ochre, which almost exactly corresponds to the values of these para-

* Numbers in the margin indicate pagination in the original foreign text.

meters for Martian continents: $r = 0.18$ and $D = 1.13$. A further refinement of such conclusions should evidently be based on spectrophotometric data, i.e., on a comparison of the curves of the spectral reflectance for the Martian surface with analogous curves for terrestrial specimens. The results of such a comparison are given in this article.

For a comparison with the data of terrestrial materials, we used the curves of the relative spectral distribution $j(\lambda)$ for Mars in the visible spectrum region. All curves were reduced to the value $j(\lambda) = 1$ at $\lambda = 560 \text{ m}\mu$. The curves were plotted from literature data pertaining to three light characteristics of the planet.

First, we used the results of colorimetric and spectrophotometric observations of the integral light of Mars which ultimately gave us the spectral distribution curve for the geometric albedo. The following materials were used: the observations by Ye.L.Krinov (Bibl.4) of 1935 performed with a short-focus camera with an objective prism, at the Observatory of the P.F.Lesgaft Institute; the photographic observations by Woolley (Bibl.5, 6) carried out at the State Observatory in Australia in 1952 and 1954; the observations by Yu.V.Glagolevskiy and K.I.Kozlova (Bibl.7) in 1955 made on the Bredich astrograph with an objective prism, at Alma-Ata; and the observations by Vaucoulers (Bibl.8) of 1958 with a standard photoelectric star photometer at the Lowell Observatory. The results of the observations are plotted in Fig.1.

Second, we used the observations of the apparent spectral brightness for the continents at the center of the disk. By the term "apparent brightness" we mean the directly measured value of brightness of the given area of the disk, which includes all the effects associated with the planet's atmosphere. The following observations were used: Sytinskaya's observations (Bibl.9) of 1939 on

the astrographic telescope at the Tashkent Observatory in five spectrum regions; the spectrophotometric observations obtained by N.A.Kozyrev (Bibl.10) in 1954

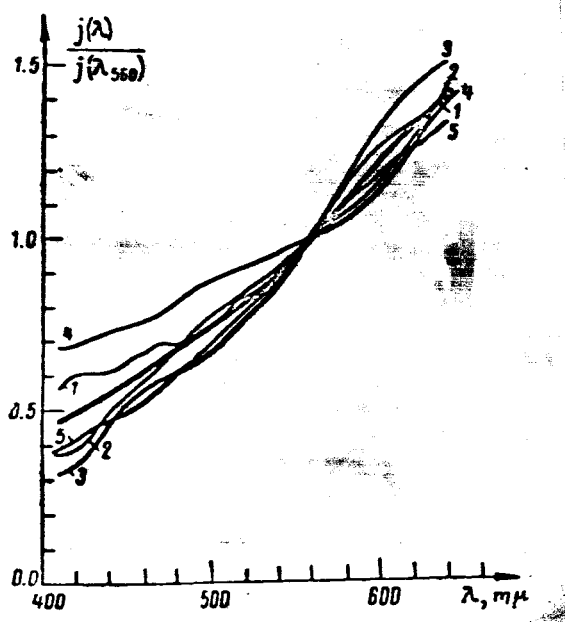


Fig.1 Spectral Distribution Curves $j(\lambda)$ for the Integral Albedo of Mars
Observations: 1 - Krinov, 1935; 2 - Woolley, 1952; 3 - Woolley, 1954; 4 - Glagolevskiy et al., 1955; 5 - Vaucoulers, 1958

with the 50-inch reflector at the Crimea Observatory by means of a slit spectrograph; the observations by Guerin (Bibl.11) performed in 1960 by means of a spectrograph set up at the Cassegrain focus of the 80-cm telescope at the Upper-Provence Observatory; the observations by Ye.I.Didychenko, I.K.Koval' and A.V. Morozhenko (Bibl.12) performed in 1961 at the State Astronomical Observatory, 127 Ukraine Academy of Sciences, on the ASP-5 spectrograph set up at the Cassegrain focus of the 70-cm reflector AZT-2. The above observations, plotted in Fig.2, were separated in time by long intervals, so that the existing appreciable scattering of the test points is attributable not only to errors of measurement but also to actual changes on the surface and in the atmosphere of the planet. However, the resultant data for the integral light of Mars and for continents

at the center of the disk can be compared with the spectral curves for specimens of the earth's mantle only in first approximation because of the fact that, in measuring the terrestrial specimens, the atmosphere has no influence whereas the

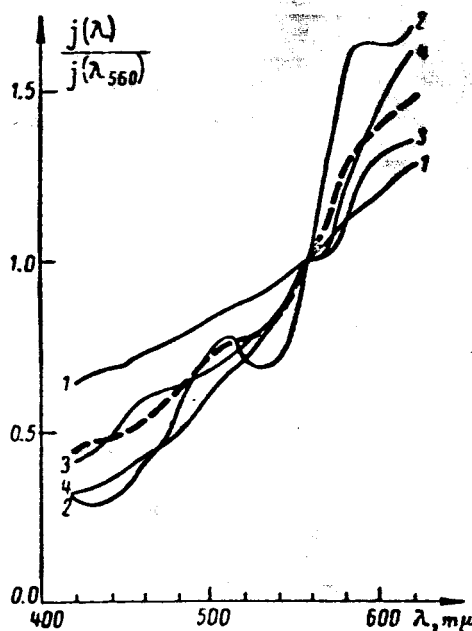


Fig.2 Spectral Distribution Curves $j(\lambda)$ for the Brightness Factor of Continents in the Center of the Martian Disk
Observations: 1 - Sytinskaya, 1939; 2 - Kozyrev, 1954;
3 - Guerin, 1960; 4 - Didychenko et al., 1961

surface of Mars is observed through its gaseous envelope whose density and composition are not accurately known. It is common knowledge that, in observing the disk of a planet from without, the haze of the light scattered in the planet's atmosphere is superposed on the disk, so that the dark areas of the surface will appear lighter and bluer. However, the material at our disposal justifies the belief that the optical density of the Martian atmosphere is so insignificant in the long-wave region of the visible spectrum that its effect on the observational data can be disregarded in first approximation. Nevertheless, in the blue-violet spectrum region, its effect becomes appreciable and must be taken into consideration under all circumstances.

Third, it is known that many authors, in addition to the apparent brightness, use the values of Lambert's albedo (depending on the method of calculation, this can be the brightness factor or the brightness coefficient); Fig.3.

In this case, the effect of the Martian atmosphere is considered excluded by /128

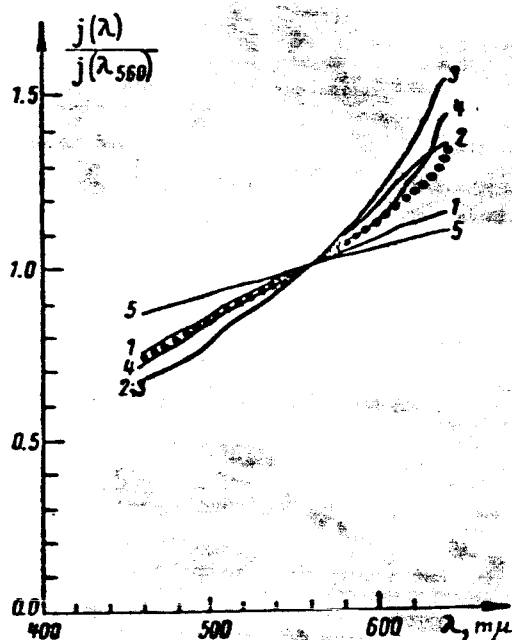


Fig.3 Spectral Distribution Curves $j(\lambda)$ for Lambert's Albedo of Continents in the Center of the Martian Disk
Observations: 1 - Barabashov et al., 1934; 2 - Sytinskaya, 1939;
3 - Barabashov et al., 1950; 4 - Koval', 1954;
5 - Barabashov et al., 1956

means of some computational procedure. This process is always based on some system of hypotheses expressing the scheme of the Martian atmosphere accepted for the particular calculation. These schemes may differ for different authors, so that the results are not only conditional but, generally speaking, can also not be compared. Nevertheless, it is of interest to use them for plotting the spectral curves and for comparing the results with those obtained from an investigation of terrestrial materials. Such a reduced spectral curve was obtained on the basis of observations made at the Khar'kov Astronomical Observatory

on the 200-mm Zeiss refractor with optical filters: in 1934 by N.P.Barabashov and B.Ye.Semeykin (Bibl.13); in 1950 by N.P.Barabashov and A.T.Chekirda (Bibl.14); in 1954 by I.K.Koval' (Bibl.15), and in 1956 by N.P.Barabashov and I.K.Koval' (Bibl.16). The above-indicated data by N.N.Sytinskaya were also used. The derived mean spectral curve, representing the most probable energy distribution in the spectrum of the light reflected by the Martian continents /129 at the center of the disk and freed from atmospheric effects as much as possible, can be considered as the most suitable for comparison with the spectral curves of terrestrial specimens.

In selecting the terrestrial materials for the spectrophotometric study we started from the principle of taking only those types of soils and rocks for which visual colorimetry gave a value for the yellow color index D reasonably close to that obtained for Mars. It is evident that, if the values of D do not agree, we cannot expect the spectral curves to agree.

On the basis of the above statements, the following types of natural terrestrial ground cover were taken for the spectrophotometric measurements (a total of 34 specimens): 1) red sands of the Luga stage of the Devonian; 2) strongly ferruginous sands from corresponding horizons of subsoil, forest podzolic soils (hardpan); 3) swamp soils rich in ferric oxide; 4) "terra rossa" - a type of red earth widespread among the karst coastal areas of the Adriatic Sea; 5) earthy, greasy varieties of limonite of the iron ocher type. All specimens were measured on the SF-2M self-recording spectrophotometer belonging to the Photocatalyst Laboratory of the Physics Institute of the Leningrad State University. The standard was BaCO_3 powder whose brightness coefficient was taken as unity for all wavelengths. The standard and the investigated specimen during the measurements were placed in special cuvettes with a glass surface through

which the measurements were made. The curves of the spectral brightness coefficients in the 430 - 740 mμ wavelength interval were automatically traced on special forms, from which we then recorded the values of the spectral brightness coefficients $r(\lambda)$ every 10 mμ. Figure 4 shows the mean curves of the spectral reflectance of specimens of red rocks relative to the value $r(\lambda) = 1$ at 560 mμ, and the mean curves of the spectral energy distribution $j(\lambda)$ for Mars: namely,

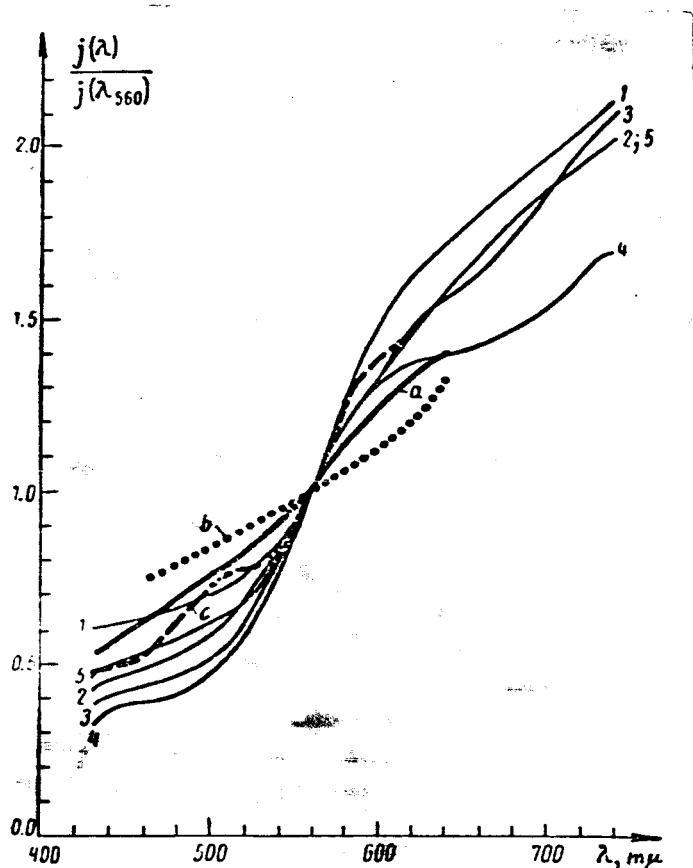


Fig.4 Mean Curves of the Relative Spectral Reflectance

$$\frac{r(\lambda)}{r(\lambda_{560})} \text{ for Specimens of Red Rocks:}$$

1 - Devonian red sands; 2 - Hardpan; 3 - Strongly ferruginous swamp soils; 4 - "Terra rossa"; 5 - Ocherous limonite. Mean curves of the spectral distribution $j(\lambda)$ for the three light characteristics of Mars: a - for the integral albedo; b - for the brightness factor of the continents at the center of the disk; c - for Lambert's albedo of the continents at the center of the disk

for the integral light of the planet (solid heavy line), for the apparent brightness of the continents (broken heavy line), and for the brightness of the continents freed from the optical effect of the atmosphere (heavy dots). As is apparent from the diagram, there is a certain similarity between the curves for the terrestrial specimens and for Mars, which can be interpreted as a confirmation of the hypothesis that considers limonite, a mineral having the composition $\text{Fe}_2\text{O}_3 + n\text{H}_2\text{O}$, as the main pigment imparting the characteristic reddish color to the Martian surface. In our case, the greatest similarity with the curves of the terrestrial specimens was demonstrated by the value of $j(\lambda)$ for the apparent brightness of the continents at the center of the Martian disk. The data reduced for the Martian atmosphere reveal a slightly less distinct similarity, /130 to which we should not attribute particular significance since the selection of the specimens was random and since somewhat differing data can be obtained for a different group of terrestrial materials.

Thus, our result can be considered as a confirmation of the hypothesis according to which the color of Mars is determined by the presence of a large quantity of hydrated iron oxides in the surface layers of the soil of this planet.

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